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EFFICIENT METHODS FOR VALIDATING TARGET ACQUISITION MODELS

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1. SUMMARY

On the basis of target acquisition fundamentals the camouflage assessment model CAMAELEON is presented and especially demands, principles and methods for validating the model. By indirect varying the distance to a target using zoom techniques of telescopes effective methods for validating the model have been developed in the visual range as well as in the infrared range.

The paper presents the results of validation studies in the visual range and results of CAMAELEON model calculations with the SEARCH DATA image set made available by the TNO Human Factors Research Institute.

The results are discussed on the basis of the underlying principles of the CAMAELEON model and the SEARCH DATA evaluations especially of visual lobe.

Further investigations on the development of CAMAELEON are presented on the basis of the gathered experiences.

Keywords: Target acquisition, validation, detectability, detection, perception, visual lobe, camouflage, visual, infrared

2. INTRODUCTION

A shortcoming of many target acquisition models is their lack of validation. The main reasons for this lack may be the following:

- Target acquisition models in many cases are very complex with numerous parameters. To cover and/or control all these parameters the statistical sample size in validation field trials has to be very large for significant results.
- Military field trials with a lot of test persons and military target acquisition tasks are time and cost consuming. Because of restrictioned funds and time, field trials often do not result in a sufficient sample size for validating target acquisition models.

	Definition	Depends on	Characteristics
1. Detectability	ability to distinguish between object and background, decides, whether a certain object **can** be detected	size luminance contrast texture color shape primitives motion	„global“ perception low level vision preattentive, without cognitive processes („automatically“) figure ground separaration texture segregation low intra- and inter-individual variability
2. Detection	classification into objects and background (in a real world, e.g. military , natural environment), decides, whether a certain object **is** detected	in addition to 1.: varying weather conditions visual complexity of natural scenes search process, search area „briefing“ of the observers attention, fatigue, training	takes place, if the object is detectable according to 1. **and** if the object is „fixated“
3. Recognition	classification of objects, e.g. into types (generic classification)	in addition to 1. and 2.: shape detection (general) knowledge of the observers	„specific“ perception recognition of details for classification
4. Identification	classification within type into e.g. military individuals (specific classification)	in addition to 1. - 3.: (specific, e.g. military) knowledge of the observers	„specific“ perception recognition of details for specific classification

Table 1. Target acquisition fundamentals

Paper presented at the RTO SCI Workshop on "Search and Target Acquisition", held in Utrecht, The Netherlands, 21-23 June 1999, and published in RTO MP-45.

To get an answer on how to overcome these shortcomings Table 1 gives a survey of target acquisition fundamentals. Generally speaking from 1. (detectability) to 4. (identification) we find the following coherences:

a. Perception process: *in*creasing complexity
*in*creasing intra- and inter-individual variability

b. Modeling: *de*creasing knowledge about the perception process
*in*creasing number of parameters
*in*creasing complexity of the models

c. Validation: *in*creasing number of parameters to be controlled
*in*creasing interfering effects (weather conditions, learning, motivation, etc.)
*de*creasing statistical significance
*in*creasing necessary statistical sample size
*in*creasing demand of resources (cost and time)

So mainly two things should be done: *The target acquisition models should be reduced to the basics of the acquisition process* (as far as possible, depending on the object and use of the model), and *the validation field trials should be adapted to the question of the model.*

3. CONCEPT OF CAMAELEON AND VALIDATION

CAMAELEON is a computer model developed for the *assessment of camouflage* using digital image processing techniques based in part on the human visual system (Hecker, 1992).

As camouflage mainly depends on the similarity between an object and the nearby background, CAMAELEON is confined to the basics of acquisition in the sense of section 2. It aims at measuring the physiological *detectability* of an object against the nearby background by describing the similarity between object and background relating to first order statistic features like *contrast* and textural features like *local contrast (energy), local spatial frequency and local orientation.*

These local textural features are calculated from the output of several bandpass-filters which are similar to the filters constituted by the receptive fields of the neurons in the early stages of the human visual system.

For object and background separately the histograms of these local features and their overlaps can be calculated to obtain measures for similarity between object and background.

These similarity measures are combined in a heuristical detection model to calculate the detectability probability as a function of range and the detectability range.

Based on this concept of the CAMAELEON model the main principles of the field trials carried out to validate CAMAELEON are:

a. *Direct measurement of the detectability ranges of the objects.* The subjects know the position of the object. By varying the distance to the object they have to mark the distance from where the object just can no longer be discriminated from the background (or respectively only just the object can be discriminated from the background).

b. *Small objects.* This avoids large detectability ranges, reduces the duration of measurements, thus reducing interfering effects, especially atmospheric effects because of relatively constant surrounding conditions during the measurements. In addition no time consuming changing of objects and position of objects and the subjects were necessary.

c. *Indirect variation of the distance from the subjects to the object* by using zoom techniques of a special telescope and thus having *constant distances to the objects* with *no interfering atmospheric effects.* This further reduces the duration of measurements, increases the probability of constant surrounding conditions and permits tests of many different objects and backgrounds in a short time.

d. *Controlled variation of the parameters which do influence the detectability* ***and*** *are subject of the CAMAELEON model:* Size, contrast and texture.

e. *Controlling as far as possible the parameters which do influence the detectability, but are* ***not*** *subject of the CAMAELEON model:* Reduced variability of light conditions (see c.) and colors of object and background, constant shape of the object.

f. Parallel to the field tests *taking the images of the scenes* from the observer positions for further evaluation with the CAMAELEON model.

These principles were applied to field trials in the visual range as well as in the infrared range.

3.1. CAMAELEON Validation in the Visual Range

From Fig. 1 it can be seen, that for the field trials in the visual range only one observation point has been chosen with the measuring telescope and the camera. Five different target positions and according to this five different backgrounds have been chosen. So with 8 different targets of different size and texture in total 40 different scenarios for one trial session could be utilized. The distance of the observation point to the targets was 30 m.

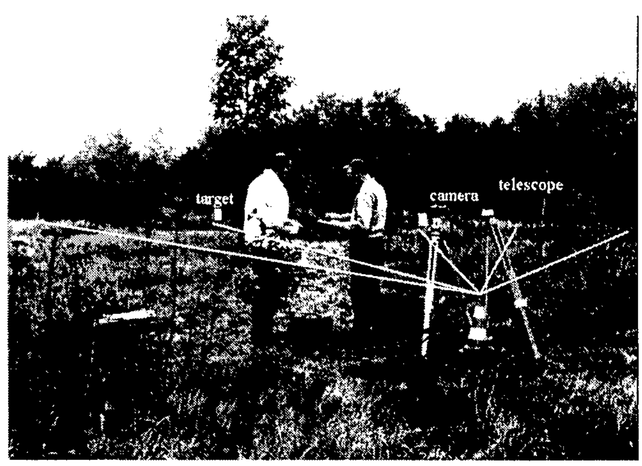

Fig. 1 Scene of the validation field trials in the visual range

Fig. 2 shows examples of chosen scenarios with different textures of object and background.

The measuring telescope from CARL ZEISS (Fig. 3) was used inverse and the subjects had to look through the object lense. Thus the measuring telescope had a reducing effect. To guarantee that the observers had a central view through the object lense, a tubus with a hole of 10 mm in diameter was attached in front of the object lense.

A specific scaled tuning of the adjustment control simulated a specific distance to the target. This scaling has been realized in a preceding study, so in the field trials *changing the distance to the targets was achieved by tuning the adjustment control.*

Fig. 2 Examples different textured objects and backgrounds

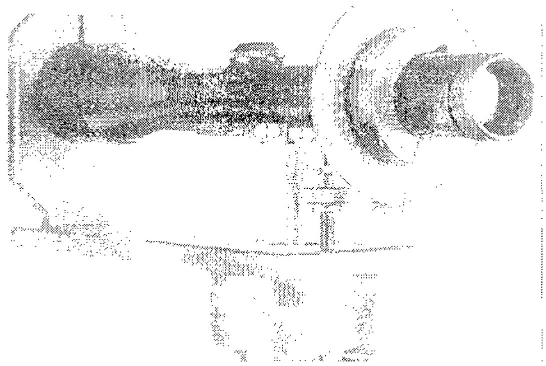

Fig. 3 Measuring Telescope with adjustment control

The apparent distance range which could be be tuned in the field trials was from 37.5 m to 600 m.

With the techniques described above a very short duration of measurements could be achieved, and within a one week trial it was possible to get a sample size of up to 120 for three to five observers.

In preceding studies it was found a very high consistency among observers, that is the inter-individual correlation was greater than 95%. So only few observers are necessary for the validation studies.

The calculation of the CAMAELON model weighting factors by correlation maximizing of measured and calculated detectability ranges has been done with a sample size of 120 assessed images.

As a result CAMAELEON showed $r = 0{,}81$ correlation (PEARSON) with another set of 120 assessed images, that is *$r^2 = 66\%$ of the variability of the measured detectability ranges could be attributed to the CAMAELEON model.*

3.2. CAMAELEON Validation in the Infrared Range

The same principles for validation as described in section 3. have been applied to the infrared range. Especially the distance to the objects has been kept constant. Instead of this varying distance has been simulated by changing the variable zoom of the used standard IR system TICM II (8_{μ} - 12_{μ}).

In the field trials only videos were taken of the scenes while zooming the scene within the whole zoom range. The videos can be evaluated later with subjects in a room with dusky illumination. The subjects have to stop the video, when the object just can no longer be discriminated from the background (or respectively only just the object can be discriminated from the background). From special marks in the IR-images the simulated distance to the object can be recalculated.

A major problem was to get temperature stabilized thermal textured IR-targets. This problem has been solved by using heatable and temperature stabilized boards, reflecting the radiance via aluminium targets to the observer. Texture has been created by paintings on the aluminium targets, thus varying the emissivity of the target surface.

Fig. 4 shows the setting up of the used equipment. To not disturb the measurements the heatable board has been "camouflaged" by IR effective nets in the direction of the observer.

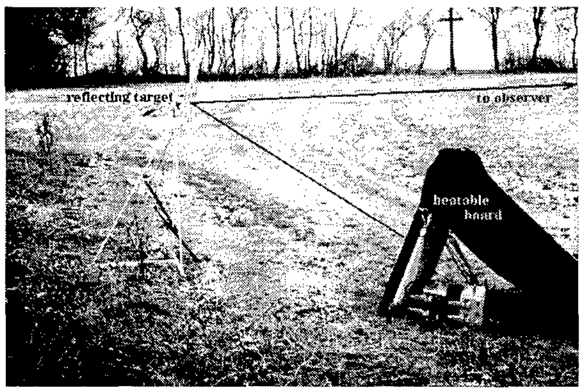

Fig. 4 Scene of the validation field trials in the IR range

In Fig. 5 an example of a IR-scene with a simple thermal textured object can be seen. On the bottom right parts of the covered heatable board can be seen.

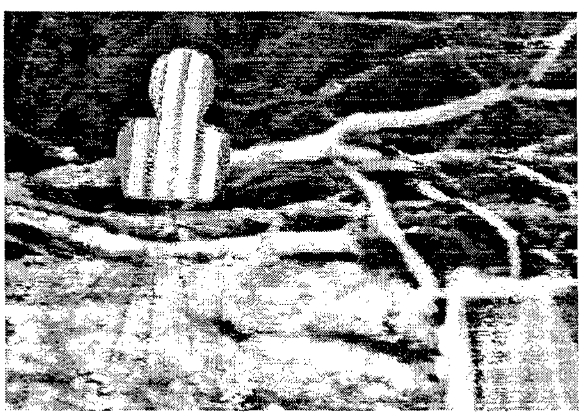

Fig. 5 IR-scene with simple textured object

Till now the CAMAELEON model doesn't contain an infrared sensor model, so in a first step only the correlation between measured and calculated detectability ranges can be calculated.

Because of small sample sizes till now and problems with getting calibrated data from the images evaluation has not

been finished yet, but the method itself seems to be very effective, although because of higher technical expenditure the number of evaluable scenes in a certain period of time is much less then in the visual range.

Analyzing the available data and the data from other IR studies suggest, that in many cases the thermal contrast between object and background is so high ("hot spots") , that according to the large detectability ranges textural features don't play a dominant role concerning detection, so CAMAELEON for the infrared range has to be adapted to this special situation.

4. CAMAELEON RESULTS ON THE SEARCH DATA

Two main aspects have to be considered when analyzing the Search Data (Toet et al., 1998) with CAMAELEON:

First CAMAELEON has been validated with standardized images, that is: taken from nearby, high resolution images of the objects, no atmospheric effects, while the images of the Search Data where taken from a wide variety of distances. This also results in a wide variety of object sizes and resolution of the objects in the screen situation which has been used for evaluation of the Search Data.

Second CAMAELEON tries to measure *detectability range* analyzing the nearby surround of the target, that is

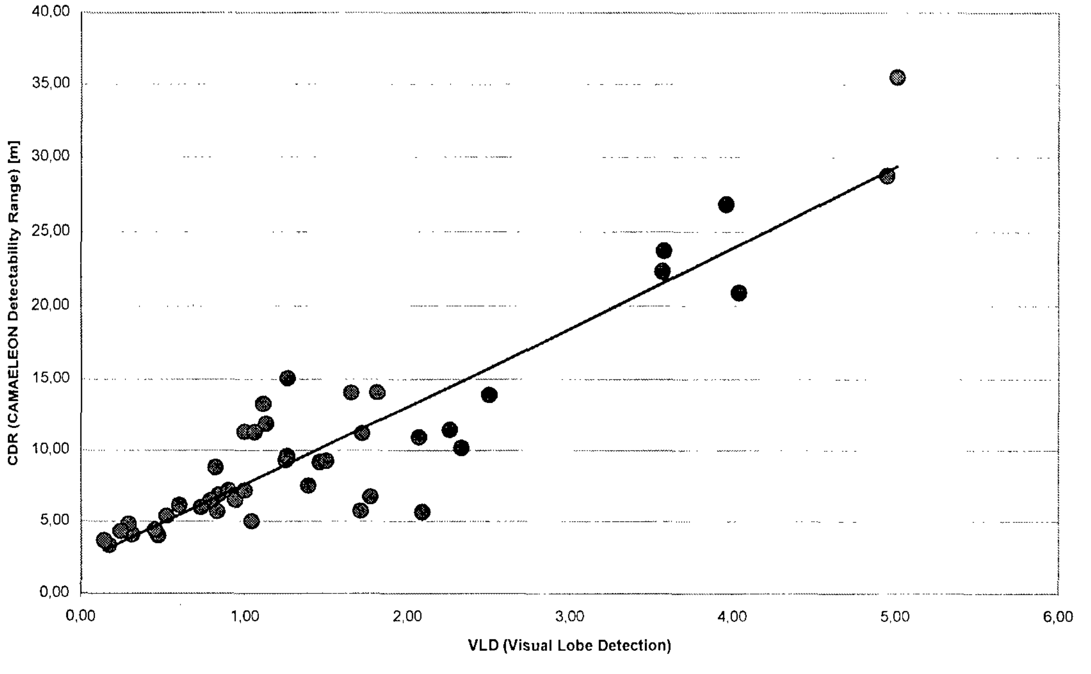

Fig. 6 CAMAELEON Detectability Range - Visual Lobe Detection

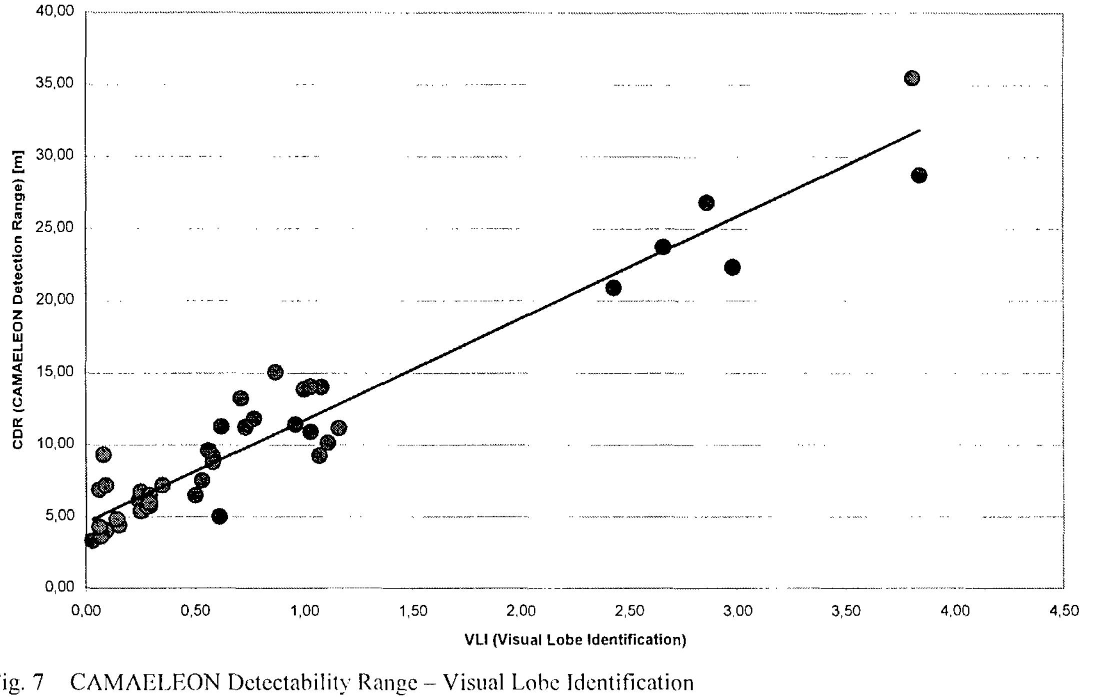

Fig. 7 CAMAELEON Detectability Range – Visual Lobe Identification

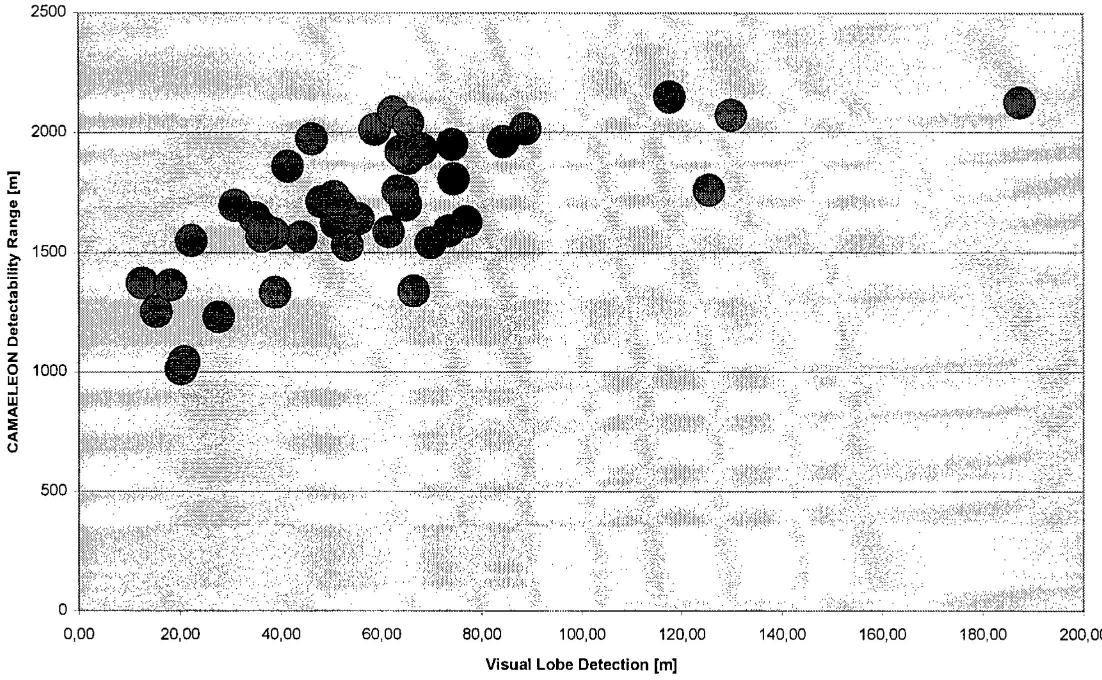

Fig. 8 CAMAELEON Detectability Range – Visual Lobe Detection („real word")

CAMAELEON uses *local metrics*, while the Search Data have been evaluated with *visual lobe* and *search time*, which also depend on the overall structural composition of the scene.

In the sense of section 2. the *Search Data field trials are not adapted to the question of the CAMAELEON model.*

So in general it is expected that the CAMAELEON results should be worse than those of (validated) models which involve *semi-local metrics* and /or *global conspicuity metrics* of the overall scene.

In particular it is expected, that the CAMAELEON results depend on the viewing distance of the Search Data images, that is the results should become better with decreasing target to the camera distances and thus decreasing the difference between nearby area around the target and entire scene.

As CAMAELEON doesn't include higher order processes as searching, the search time results of the Search Data have not been compared with CAMAELEON results.

4.1. Evaluation of the screen situation

In a first step the detectability ranges in the screen situation have been calculated, that is all targets had the same distance to the observer, the size of the targets was that of the size of

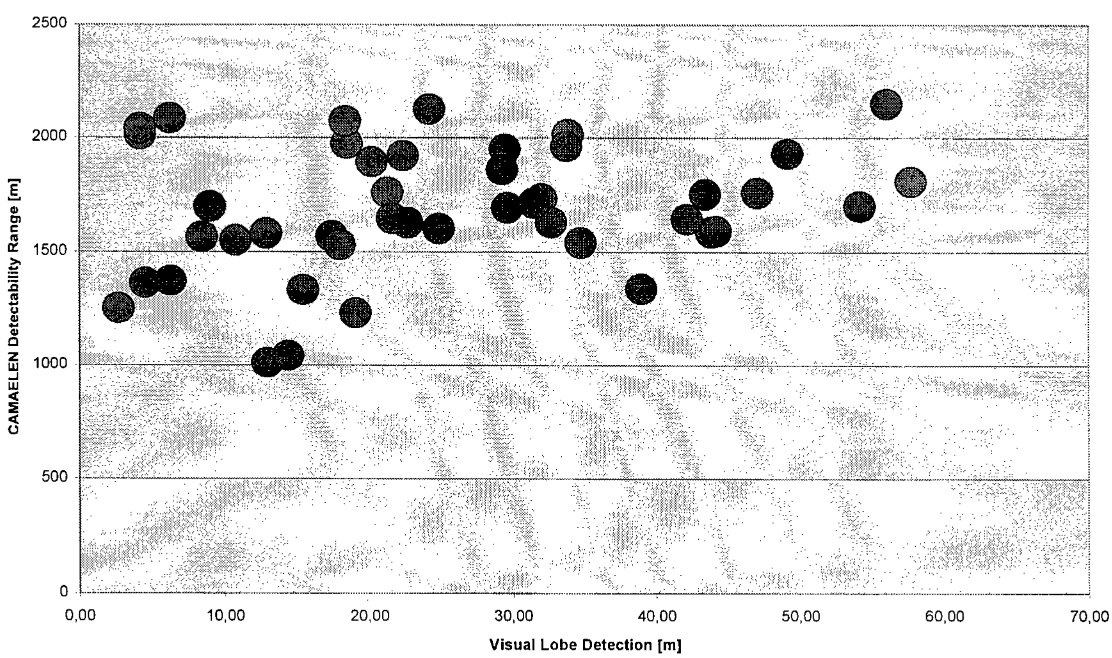

Fig. 9 CAMAELEON Detectability Range – Visual Lobe Identification („real word")

the targets on the screen. Because of the wide variety of distances the images were taken there also was a wide variety of object sizes on the screen, from which of course the visual lobe and the detectabiltiy ranges depend on.

Fig. 6 and Fig. 7 show the diagrams of CDR (CAMAELEON Detectability Range) versus VLD (Visual Lobe Detection) and VLI (Visual Lobe Identification) respectively. As expected because of the wide variety of object sizes the correlation is very high (PEARSON r^2 = 84% and 92% respectively). Proceeding from the fact, that the PEARSON correlation between the Square Root of Object Size (on the screen) and VLD and VLI respectively is r^2 = 73% and 86%, the "gain" resulting from CAMAELEON compared with Object Size only is 11% and 6% respectively.

To really judge about a detection or detectability model and/or compare it with others from our point of view it is absolutely necessary to hold object size constant as far as possible, that is in this case to take all the images from the same distance (as has been done in the CAMAELEON validation field trials). Otherwise you get interfering effects with different cues (size, atmosphere, resolution, contrast, texture) which cannot be resolved afterwards.

4.2. Extrapolation to "real world" situation

Another approach to the Search Data is to extrapolate the CAMAELEON calculations for the "real world" situation, that is here to calculate with the object sizes in the distance the images were taken from.

In this case the calculated CAMAELEON detectability ranges have to be compared with the Tangens of the Visual Lobe multiplied by the Distance. By this way we get the "real" visual lobe (in meters, not angle), and the object sizes vary in the natural ratios. On the other side we have these interfering effects in the images mentioned above resulting from taking the images from different distances, which should be avoided for CAMAELEON calculations.

Fig. 8 and 9 show the diagrams of CDR_r (CAMAELEON Detectability Range "real world") versus VLD_r (Visual Lobe Detection "real world") and VLI_r (Visual Lobe Identification "real word") respectively. The data are divided in two subgroups, *red* for short distances (sd), *green* for long distances (ld) the pictures were taken from), to support the hypothesis, that the CAMAELEON results should be better for short distances (see section 4). The correlation results are listed in Table 2.

	Pearson r^2	Pearson r	Spearman
CDR_r-VLD_r total	0.45	**0.67**	**0.68**
CDR_r-VLD_r sd	0.61	0.78	0.59
CDR_r-VLD_r ld	0.42	0.65	0.69
CDR_r-VLI_r total	0.06	**0.18**	**0.25**
CDR_r-VLI_r sd	0.44	0.66	0.52
CDR_r-VLI_r ld	0.02	0.14	0.20

Table 2 Correlation results (explanation see text)

It seems as if the hypothesis is supported (except Spearman for Visual Lobe Detection), but significance may be low because of the small sample size of images evaluated. The correlation with Visual Lobe Identification is very low, but in this case the difference between short and long distances is much higher than according to visual lobe detection. It supports the assumption, that CAMAELEON would give better results with standardized high resolution images of the targets taken from small distances.

5. CONCLUSIONS

Of course the results are not satisfactory. This is partly due to the special demands CAMAELEON makes on the quality of images and on the method of field trail evaluation (detectability as defined above instead of visual lobe).

On the other side the CAMAELEON model lacks further important features which influence the detectability of targets as color and luminance level (CAMAELEON has problems with gloss for example) and shape primitives. Another problem which makes detection modeling so complex and is not solved at all - neither in the CAMAELEON model nor in any other detection models – are ***the interfering effects of different cues.*** In the moment the CAMAELEON features are combined in a simple detection probability model assuming independence of the different cues with constant weighting factors. This may be wrong, but is hard to analyze from the scientific and modeling side as well as from the validating side.

Starting point for further development is the question of the CAMAELEON model, that is the assessment of camouflage. So it is not intended to expand CAMAELEON to a detection model, which is able to calculate search time and visual lobe in an entire scene as defined for example in the Search Data.

Detection really also depends on parameters of the overall scene, but these cannot be influenced by camouflage in a narrower sense.

So further investigations instead will be done on the features already used, luminance level, color and shape primitives and their interactions concerning detectability.

6. REFERENCES

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